EN200

LAB #13

SUBMARINES AND SUBMERSIBLE VESSELS

Instructions

1. This lab is **conducted in the hydrolab** on the lab deck of Rickover Hall.

2. You will need to **bring this lab to the lab period**.

3. The lab is to be performed in small groups of 2 or 3 but **each member of the lab group is to submit their own work**. You can ask questions and discuss the content of the lab, but the submitted work must be your own.

4. **Follow the stages of the lab consecutively**. The lab follows a logical thought pattern, jumping ahead without doing the intervening theory questions will limit your understanding.

5. **All work must be shown on your lab for proper credit.** This means that you must show generalized equations, substitution of numbers, units and final answers. Engineering is communication. Other people should be able to understand your work.

6. **This lab is to be submitted at the end of the lab period**. Do not be alarmed if you have not completed the whole lab. It is far better for you to understand the work than rush through it in an attempt to finish. You will not be penalized for an incomplete lab.

Student Information:

Name: ____________________________

Section: __________

Date: ____________

Aim:

- Familiarize the student with the drag and heave forces experienced by a submerged body.
- Reinforce the students understanding of the submarine hydrostatics
- Reinforce the students understanding of the submarine stability.

Part 1: Lab Description

Information

1. The lab consists of 2 separate parts.

- **Submerged Body Forces.** In the first part of the lab, several towing tank runs will be performed with a submersible at different speeds and depths below the surface. Heave and drag forces will be analyzed.
- **Neutral Buoyancy and Stability.** The second part of the lab consists of a series of experiments on a submerged body. This part is performed in lab groups.

Apparatus

2. The apparatus for the first part of the lab consists of a submersible attached to the 120' towing tank carriage by a fwd and aft post, posts 1 & 2 respectively. The force block configuration is set up to record X and Z forces on each post. The setup is shown at Figure 1.

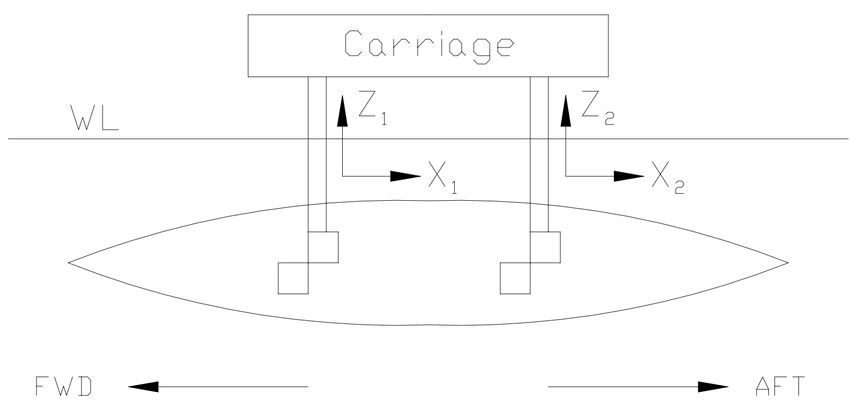

Figure 1 – Tow Tank Arrangement for Submersible

3. The apparatus for the second part consists of a 1 liter submersible floating in a tank. Various weights are provided for ballasting and a protractor to measure trim angles.

Part 2: Tow Tank Testing

Heave and Resistance Forces at Constant Depth

1. The submersible is set at 1½ diameters below the waterline and towed at increasing speeds. Computer software analyzes the data and records the heave and resistance forces being experienced by the submersible on each towing post.

2. Use the data being presented by your instructor to complete this results table.

Submersible Depth Set at 1½ Diameters				
Speed V_M (ft/s)	Heave Force Fwd Post Z_1 (lb)	Heave Force Aft Post Z_2 (lb)	Total Heave Force Z (lb)	Total Resistance X (lb)
2.0				
3.0				
4.0				

3. What is happening to the heave force as speed increases? ___________________________

4. Why does this occur? You may wish to refer to Bernoulli's Theorem in your answer.

____

____

____

____

5. What is happening to the total resistance as speed increases? _________________________

6. What component of resistance is dominating the change in total resistance as speed increases?

____

Heave and Resistance Forces With Changing Depth

7. 3 further runs are made with the towing apparatus for this segment of the lab. This time the speed of the run is held constant, but the depth of the submersible below the surface is changed. Once again, we will measure the heave and resistance experienced by the model.

8. Use the data presented by your instructor to complete this results table.

Submersible Speed Set at 5 ft/s				
Depth	Heave Force Fwd Post Z_1 (lb)	Heave Force Aft Post Z_2 (lb)	Total Heave Force Z (lb)	Total Resistance X (lb)
1½ Diameters				
1 Diameter				
½ Diameter				

9. What is happening to the resistance as depth decreases? ___________________________

10. Using your knowledge of ship resistance, what should be happening to the Viscous Resistance (R_V) as the submarine gets closer to the surface?

____

Why? ____

11. Using your observations of the different tows, what is happening to the Wavemaking Resistance (R_W) as the submarine gets closer to the surface?

____

Why? ____

12. Comparing your answers above with the towing results, which component of resistance is more dominant for the model traveling at 5 ft/s near the surface?

____

13. Where should a full-scale submarine operate in order to achieve maximum speed?

____

14. What is happening to the heave force as the submarine gets closer to the surface?

____

15. What is causing the heave force to change as the submarine approaches the surface?

____

____

16. What happened to the heave forces when the submarine was at a depth of ½ diameter?

____

____

17. Give 2 measures a submarine can take to minimize the possibility of detection and minimize the effects of heave when traveling close to the surface:

Measure 1: ____

Measure 2: ____

18. In the space below, sketch 2 plots of total resistance: one with the submarine at constant depth and varying speed, and the second being a plot of total resistance as depth decreases.

Part 3: Neutral Buoyancy and Stability

Initial Tasks

1. In this part of the experiment a 1 liter plastic bottle with an aluminum yoke around it is used to model a submersible vehicle. Located on the yolk are 4 long bolts. These act as locators for the addition of weights. Bottom weights are permanently attached to the yolk to achieve sufficient stability. A plan view of the arrangement is at Figure 2.

2. Using a scale, weigh the model with only the bottom weights attached and record this weight in the appropriate space in the Figure.

   Similarly, measure and record the distance between the bolts.

Neutral Buoyancy

3. Add equal weights to each of the bolts such that the model becomes neutrally buoyant. Do not adjust the bottom weights. If the model develops a trim when neutrally buoyant, slide the bottle in the yoke to achieve zero trim.

   Record the data and complete Figure 2.

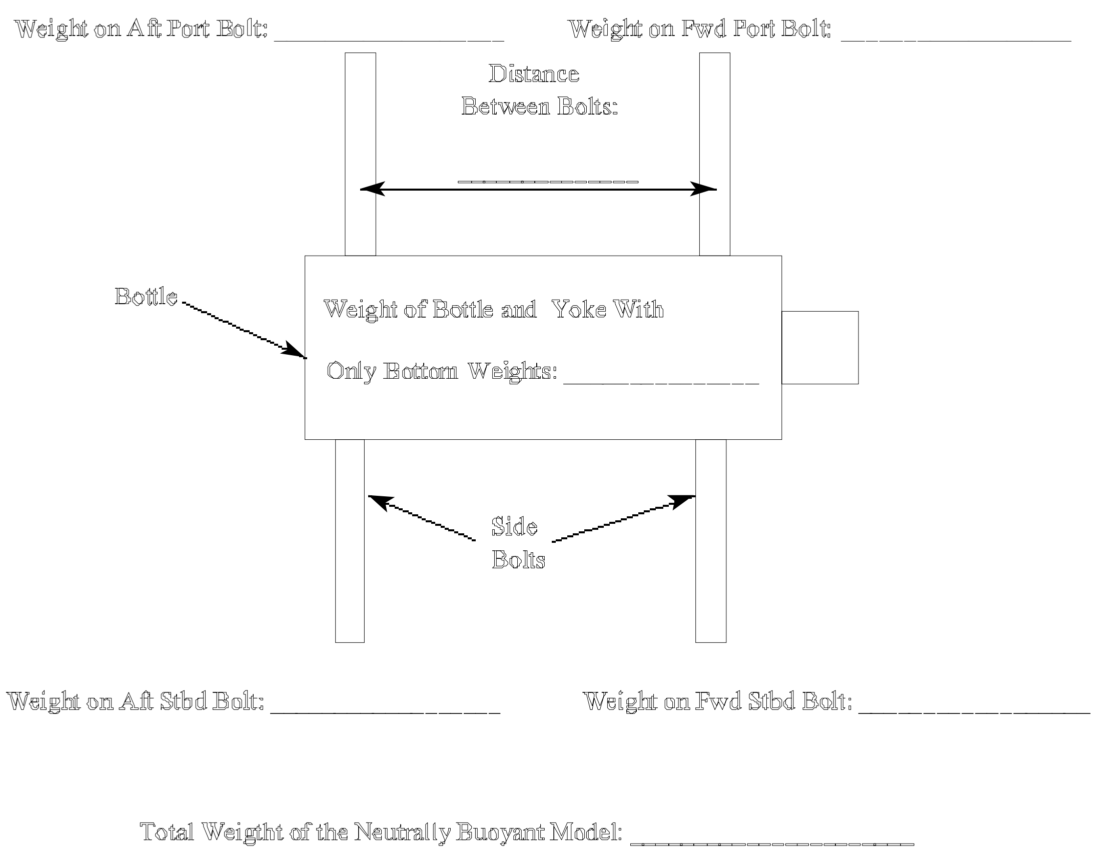

Figure 2 – Plan View of Submersible Model

4. With the submersible in its neutrally buoyant state, give the equation that links its displacement (Δ) with the submerged volume (∇).

5. Referring to this equation, give three environmental conditions that can effect the neutral buoyancy condition of a submersible.

Condition 1: ______________________________

Effect ______________________________

____

Condition 2: ______________________________

Effect ______________________________

____

Condition 3: ______________________________

Effect ______________________________

____

6. Draw a profile of the submerged neutrally buoyant plastic bottle at level trim. Be sure to include the center of buoyancy (B), the center of gravity (G), the resultant buoyant force (F_B) , and the displacement (Δ).

Estimation of the Distance BG

7. You will recall that many of the hydrostatic and stability characteristics of a submerged body rely upon the magnitude of the distance BG. It is possible to estimate this distance for the submersible model by causing it to trim using a known shift in weights.

8. Shift equal weights from the port and starboard after bolts to the port and starboard forward bolts so that the model has a submerged trim between 5 and 10 degrees down by the bow.

   Use the scale to record how much weight was shifted forward.

   Weight (w) = ________________________

   Refer to Figure 2 to record the distance of this weight shift.

   Distance (l) = ________________________

   Use the protractor to record the actual trim in degrees. (See note)

   Trim Angle (θ) =________________________

   Note: Measuring the trim angle is best achieved by capturing the submersible model between the tank side and protractor. Line the edge of the protractor up with the ends of the long boats and record the angle. **Take care not to influence the trim angle with the protractor.**

9. Draw a profile of the submerged neutrally buoyant plastic bottle after the longitudinal weight shift. Include the center of buoyancy (B), the original center of gravity (G_0), the new center of gravity (G_1), the resultant buoyant force (F_B), the displacement (Δ), and the angle of trim (θ).

10. With the help of the diagram you drew in the previous step, **derive** an equation for the line segment between the original center of gravity and center of buoyancy (BG_0) in terms of the angle of trim (θ), the displacement (Δ), the magnitude of the weight shifted (w), and the distance the weight was shifted (l). Show you fully understand your working by drawing the trigonometric relationships used in the derivation in the box provided.

Note: To help, you will recall that weight shift theory gives the following relationship.

$$\overline{GG_0} = \frac{wl}{\Delta}$$

Trigonometric Relationship	**Derivation**

11. Using your derived expression in the previous step, the data from Figure 2 and your recordings at 8, calculate the distance between the original center of gravity and the center of buoyancy (BG_0) for the submerged neutrally buoyant model. Box your answer.

Submarine Stability

12. With the magnitude of the distance BG_0 calculated, it is possible to assess the stability of the submerged model.

13. Figure 3 shows the cross section of the submerged neutrally buoyant model heeling due to an externally applied couple. Complete the figure by including the center of buoyancy (B), the center of gravity (G_0), the resultant buoyant force (F_B) , the displacement (Δ), the righting arm (G_0Z) and the angle of heel (ϕ).

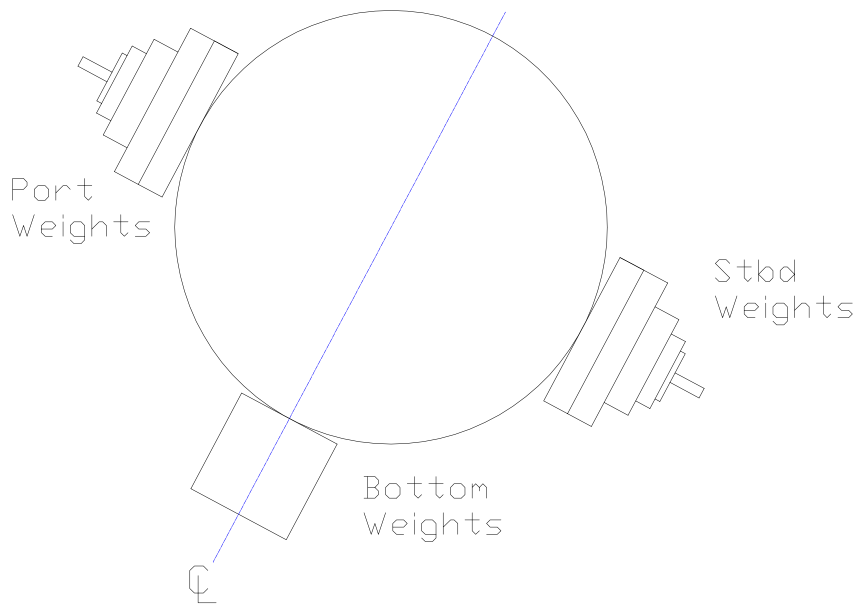

Figure 3 – Heeling Submerged Model

14. Use this figure to derive an equation for the righting arm (G_0Z) in terms of the distance between the center of gravity and the center of buoyancy (BG_0) and the angle of heel (ϕ).

15. Use this equation and your answer to part 11 to plot the curve of intact statical stability for the submerged model. You can use the graph paper on page 11.